Yield analysis of four radish (*Raphanus sativus* L. var. sativus) cultivars storage roots grown in controlled cabinets under varying temperatures and irrigation levels

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ABSTRACT: Topsi, Famox F1, Corox F1, and Altox F1 radish cultivars grown in controlled continuous 20 and 12oC cabinets and they subjected to 0, 33, 66, and 100% depletion of peat moss available water capacity (AWC). The objective of this experiment was to analyze the yield of four cultivars of radish in response to varying continuous (no thermoperiodism) temperatures and irrigation levels. The obtained results revealed that 12°C tended to hasten the swelling of hypocotyl and performed better storage root yield on the account of leaves, especially when combined with adequate irrigation. 20°C temperatures substantially increased leaves yield on the account of storage roots, particularly when combined with adequate watering. Severe drought gave reduced entire plants, storage roots and leaves yields significantly. The significance order of cultivars categorized in to the following: Altox F1> Corox F1>Famox F1> Topsi, where Topsi appeared to favour 20oC. Adequately irrigated Altox F1 grown at continuous 12oC was the paramount treatment, as it gave the best yield of plant and storage roots. Other interaction treatments discussed in the results and discussion section.

Keywords: Yield, Storage roots, leaves, Continuous Temperatures, Radish Cultivare, Irrigation, Drought

INTRODUCTION

Radish (*Raphanus sativus*) is a vegetable, which is rich in vitamins and minerals and has medicinal values. The distribution of dry mass in roots and shoots increased differences between both measurements, the increase in shoots observed. Sucrose is the transport carbohydrate most widely distributed in the plant kingdom. It forms the interface between photosynthetically active source tissue serving as an energy source for growth and development or supplying the accumulation of storage reserves such as glucose and fructose (Sirtautas , 2011). Beyond its role in energy metabolism, sucrose and its metabolites have been shown to effect the expression of genes involved in a number of metabolic pathways (Koch, 1996). Sugar beet gave the maximum leaf-area, Chl a/b ratio, stomatal conductance and photosynthesis rate and Hill activity at 125 days. However, the total chlorophyll was higher in turnip at both stages than sugar beet. The stomatal resistance was maximum in turnip at 140 days and minimum in sugar beet at 125 days. The data show that chlorophyll contents are not related to the photosynthesis rate. The latter was most profound in sugar beet at both stages as considerable amounts of photosynthates transformed into sucrose and therefore sugar beet contains over 20% sugar by weight (Siddiqui , 2006).

High moisture availability increased yield and % TSS. Higher % TSS content positively correlated to increased weight for different genotypes of radish (Lu , 2008). After four weeks, plant height was significantly higher in grass

mulch with 100% MC followed by no mulch with 100% MC, then clear plastic with 100% MC and lastly black plastic with 100% MC. Not all other treatments were significantly different from the control. All treatments that mulched had higher growth parameter values than those that were on bare soil. The height of radish under grass mulch was significantly taller than all the other treatments. There was no significant difference between black polyethylene and the control (no mulch) and these treatments resulted in the lowest plant height (Carmichael , 2012). Yield and most yield components improved with application of irrigation water in chickpea genotypes (Bakhsh , 2007). There is documented evidence that water plays a major role on the yield and quality of radish. Park and Fritz (1984) reported similar results of increased yield of radish with high levels of irrigation and fertilizer. High levels of irrigation resulted in ample amounts of water being available to the radish plants and in addition, mulching could have further assisted in moisture conservation.

Anonymous (2004) indicated that yields of root vegetables were highest when mulched and that harvest was seven days earlier when compared with non-mulched plantings. Water quantity had a direct influence on the plant height. An increase in the quantity of water resulted in taller radish plants. This demonstrated that application of water to field capacity promoted more growth in radish when compared with less water application. Yield and most yield components improved with application of irrigation water in chickpea genotypes (Bakhsh , 2007). There is documented evidence that water plays a major role on the yield and quality of radish. Park and Fritz (1984) reported similar results of increased yield of radish with high levels of irrigation and fertilizer. High levels of irrigation resulted in ample amounts of water being available to the radish plants and in addition, mulching could have further assisted in moisture conservation. Kang and Wan (2005) reported that changes of leaf area index (LAI) for the five watering treatments from seedling stage to harvest showed sigmoid shapes for the LAI versus time relationship. During seedling period, the LAI values for all treatments were small, and began to increase at leaf development stage. When near the succulent root formation stage, the LAI values of different treatments reached their maximum successively, and then decreased a little at the end of experiments.

Water stress is one of the major limitations to the agricultural productivity worldwide, particularly in warm, arid, and semi-arid parts of the world (Boyer, 1982). Drought results in the increased generation of reactive oxygen species (ROS) due to energy accumulation in stressed plants, which consume less light energy through photosynthetic carbon fixation (Smirnoff 1993; Asada 2006). Drought inhibits or slows down photosynthetic carbon fixation mainly through limiting the entry of CO_2 into the leaf or directly inhibiting metabolism (Smirnoff 1993; Loggini 1999; Apel and Hirt 2004). Plants have developed a wide range of adaptive and resistance mechanisms to maintain productivity and ensure survival under drought stress condition. To reduce the toxicity of ROS, plant cells have developed an antioxidative system, consisting of low molecular-weight antioxidants like ascorbate, α-tocopherol, glutathione, and carotenoids, as well as protective enzymes. Superoxide radicals scavenged by superoxide dismutase (SOD), while the resulting H_2O_2 is reduced to H_2O by catalase (CAT) and peroxidase (POD) (Mittler 2002; Apel and Hirt 2004; Abdel, 2014).

Drought is a highly complex issue to tackle and its research bears corresponding complexity and requires multidisciplinary approach. Research and development activities relating to this issue are broad and proceed in several directions. Efforts toward solving the problem of drought in plant production based primarily on the selection of tolerant genotypes. The conventional selection method by crossing exotic germ plasma and adapted elite material has predominated until quite recent times. Over the past several years, however, molecular markers have been used for identification of tolerance carrying genes in addition to adequate selection technology (Miletic , 2010).

High temperature affects the photosynthetic functions of plants by its effect on the rate of chemical reactions and on structural organization. It has been previously reported that high temperatures are responsible for changes in the thylakoid membrane, altering not only its physicochemical properties, but also its functional organization (Berry and Bjorkman, 1980). PSII, particularly, is the most sensitive component of the photosynthetic system (Berry and Bjorkman, 1980; Mamedov , 1993). Extreme high temperatures affect the functioning of the O,-evolving system resulting in the release of functional manganese ions from the complex (Nash , 1985). This release may be the result of reductions by peroxides or superoxides (Thomson , 1989). PSII also responds to the range of temperatures below those causing inhibition or destruction of the complex, with consequences for thylakoid organization and functioning. Separation of the LHCII from the core center induces destacking of the grana (Gounaris , 1984) and temperature induced migration of the reaction center (PSII) or LHCII (state transition) to the nonappressed region, which would have consequences for the energy redistribution between PSI and PSII.

It is clear that the content of carbohydrates mainly influenced by the combination of low temperature and long day photoperiod. However, the content of carbohydrates was similar, because after 29 days radishes reached the same level of development. Radish mainly used for salad and decorative purposes and it is in high demand in the hotel industry. Radish is a cool season vegetable root crop, which grows well under tropical conditions. However,

under tropical conditions, all time sufficient moisture availability is a challenging condition. Therefore, under tropical conditions there is need to optimize sufficient moisture availability for radish growth. The objective of this experiment was to investigate optimum water requirements of radish when using different mulching materials in a semi-arid environment. Maas and Hoffman (1977) classified radish as a crop which yield is moderately sensitive to salinity, while Sonneveld (1988) reported a low sensitivity. Although, salinity may reduce growth, raising the salinity in the root zone used as a method to enhance the quality of some vegetables (Mizrahi and Pasternak, 1985; Sonneveld, 1988).

Plant water status considered as the most important variable under changing ambient temperatures (Mazorra , 2002)**.** Plant water relation more affected under the combined heat and drought stress, than the condition of heat and sufficient moisture level **.**High temperatures affect seedlings, first, by increasing evaporative demand and tissue damage. High temperatures induced increased transpiration and water transportation is another necessary tool for plant survival under extreme temperatures. Death of a large number of *Pinus ponderosa* seedlings were observed at 63°C but among those a few were survived those maintained basal stem temperatures as much as 15°C lower than the surrounding air by keeping higher *gs* **,**transpiration rate and water transportation. Here, water transport through seedling stems may help to cool plant by the heat transferring mechanism. Heat exchange calculations demonstrated that rapid water flow through seedling stems could absorb sufficient energy to reduce the stem temperature by 30°C during peak sunlight hours (Kolb , 1996). *Wheat Triticum aestivum* and Barley *Hordeum vulgare* were grown in soil that was well watered or not watered in controlled chambers at 15/10, 25/20, 35/30 and 40/35°C day/night temperatures **.**After two days soil water content, leaf relative water content, leaf water potential, leaf osmotic potential, leaf turgor potential and osmotic adjustment were nearly constant at all temperatures when soil was well watered but were affected strongly by high temperatures (HT) when water was withheld (Machado and Paulse, 2010). Morales (2003) indicated that HT induced reduction in leaf water status was caused mainly due to reduction in hydraulic conductance leading to decrease in water absorption or due to reduced *g*. In (*Lotus creticus*) elevated night temperatures caused a greater reduction in leaf water potential in water stressed as compared to well-watered plants (Banon , 2004). In sugarcane, leaf water potential and its components were changed upon exposure to heat stress even though the soil water supply and relative humidity conditions were optimal, implying an effect of heat stress on root hydraulic conductance (Wahid and Close , 2007).

Finally, the yield of any crop is the chief indicator of productivity. It is a quantitative characteristic, which results from the interactions of many components such as plant height, root diameter and fresh and dry mass (Ali , 2003). Several factors such as temperature, light intensity, day length, rainfall, and soil moisture have a significant impact on the yield of carrots. In order to attain the highest potential yields, the crop should be grown in an environment that meets these requirements (Decoteau, 1998). Poor cultivation practices and the lack of high yielding carrot cultivars may be reasons for low yields (Siddiqui, 1995; Alam , 2010). The fresh mass of carrots (yield ton ha^{-1}) consists out of 85-90% water and 10-15% dry matter (Odebode and Unachukwu, 1997). The dry matter of carrots consists of nitrate, amino acids, amides proteins, and carbohydrates (Northolt , 2004). Niedziocha (2011) reported that one raw medium carrot weighing 78 g contains only 25 calories, of which, 23 calories or 5.84 g are from carbohydrates. These carbohydrates consist of 2.89 g of sugar, while the remainder come from fiber. Dolson (2011) stated that carrots are among root vegetables with the lowest carbohydrate content. The objective of this study is to evaluate the yield of four radish cultivars namely Topsi, Famox F1, Corox F1, and Altox F1 grown in continuous 12 and 20°C (no thermoperiodism) temperatures and subjected to 0, 33, 66 and 100% AWC depletions.

MATERIALS AND METHODS

This experiment was conducted in controlled growth cabinets at Institute Fur Gartenbauliche Produckions Systeme, Biologie, Liebniz Universitat, Hannover, Germany. The objective of this trail was to evaluate the yield of four radish (*Raphanus sativus* L. var. sativus) cultivars namely Topsi, Famox F1, Corox F1 and Altox F1 grown in cabinets of two varying (12 and 20 oC) temperatures and four varying water availabilities (0, 33, 66 and 100% depletion from the available water capacity AWC).

Untreated seeds of the evaluated cultivars were produced Verschliessung in 2013-2014, EG-Norm Standardsaatgnt DE 08-9387st. These cultivars can perform storage root of 2.5-2.75 mm diameter. Lots number of Topsi RA0002CTP (T) was 01972-007, Famox F1 RA4798CTP (F) was 00013-001, Corox F1 was 07110-000 (C) and Altox F1 (A) was 00212-007.

Experimental Design

Split Split plot with in Factorial Complete Randomized Block Design (S S F-CRBD) was chosen for the trail where Factor (A) was represented by cabinet temperature of 20°C (a1) and cabinet temperature 12°C (a2). Factor (B) was represented by four water availabilities, sustain peat moss moisture at and below field capacity 0 AWC% depletion (b1), 33% AWC depletion (b2), 66% AWC depletion (b3) and wilting point, 100% AWC depletion (b4). Factor (C) was represented by four radish cultivars namely Topsi (c1), Famox F1 (c2), Corox F1 (c3) and Altox F1 (c4). Therefore, 32 treatments were included in the trail each replicated four times with 18 plants for a replicate.

Cultural practices

Experiment conducted in two cabinets, radish cultivars in the first cabinet (figure, M1) subjected to controlled temperature 12°C, while the second (figure, M2) radish cultivars exposed to controlled temperature 20°C. Therefore, 176 plastic trays dedicated to 128 trays for investigation, besides 48 guard trays, each tray contains18 cells of 5.4749732831g dry peat moss. Trays filled with peat moss and taken to the controlled cabinets (Figures, M1, and M2) then trays were set according to the above-proposed statistical design.

Trays were brought up to field capacity on December 9th 2013, and then one seed was sown in each cell. 15 days from sowing undesired plants replaced by transplants from guard trays to maintain uniformity and then these transplants substituted by seedling grown in separate plastic plates. Immediately, after transplanting plants were brought to field capacity and irrigation schedule was commenced according to AWC % depletion adopting weighing methods with 2 decimal electrical balances. A compound fertilizer type (2 Mega special) composed of Macro nutrients NPK (Mg), 16-6-26(3,4) Magnesium. In addition to that it possesses micro nutrients precisely 0.02% B, 0.04% water soluble CU, 0.04% EDTA Cu, 0.1% water soluble Fe, 0.1% EDTA and EDHHA Fe, 0.05% water soluble Mn, 0.05% EDTA Mn, 0.01% water soluble Mo and 0.01% water soluble Zn, 0.01% EDTA Zn, EDTA with pH 3, 11 and EDHHA with pH 1 and 10. Plants were fertilized four times on 11, 20, 28 and 32 days after sowing by dissolving 5g.l^{-1} in irrigation water. Plant fresh weights recorded, and then leaves fresh weight and storage roots recorded. Exceeding % = higher value – low value/ low value. Sas 9.3 and Minitab 16.1 software used for statistical analysis and regression.
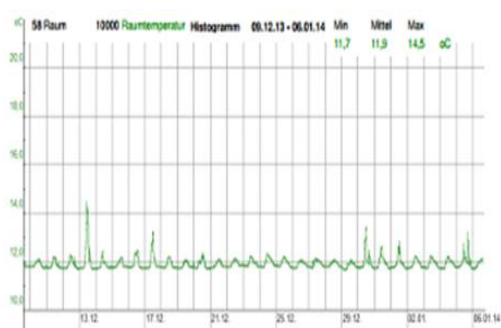

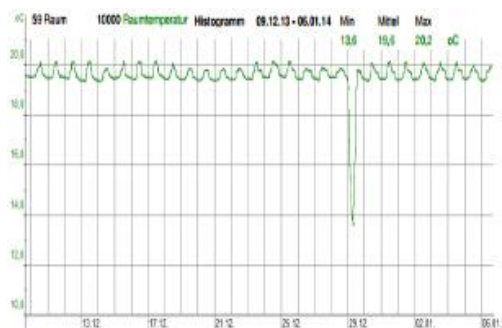Figure (M1). Temperature at cabinet 1 where radishes were grown at 12oC

Figure (M2). Temperature at cabinet 2 where radish were grown at 20oC

RESULTS AND DISCUSSION

A. Radish responses to varying temperatures

The highest plant yield (4.2964 Kg.m^{-2}), yield of storage roots (3.1529 Kg.m^{-2}) and yield of fresh leaves (1.03618 Kg.m^{-2}) observed in radish grown in 12°C cabinet (table, R1), which significantly differing from radish grown at 20°C. These results suggested that continuous (no thermoperiodism) 12°C was more suitable for radish production for yield of storage roots and leaves yield. Radish is a cool season Rooty crop, which can endure wide range of temperature. However, there is a maximum, optimum, and minimum temperature for its growth performance, as other cool season crops. Radish and Carrots are a cool season crop that performs best at temperatures between 15 and 22°C with a base temperature of 5°C (Al-Harbi , 1997; Krug, 1997; Rubatzky , 1999; Alam , 2004; Simon , 2008). Optimum day temperatures for carrot plant growth range between 21 and 22°C while optimal night temperatures are between 18 and 20°C (Alam , 2004). Carrots can endure warmer temperatures making it possible to plant carrots nearly throughout the year. In South Africa, carrots cultivated under a range of climatic conditions in various regions of South Africa for the fresh (pre-packed and bunched) and processing (dehydrated and frozen) markets (Nortje and

Henrico, 1986; Joubert , 1994). Radish roots grown under low temperature (F1, F2) were larger, grew faster and accumulated more photosynthetic products than those grown under the ordinary (18°C) temperature (F3,F4). Besides, it is well known that environmental conditions play a significant role in the regulation of root and shoot biomass (Vysotskaya, 2005). Carrot root growth depends on assimilate supplied from the leaves, the photosynthetic plant parts, and storage root growth can be estimated from the total plant growth (Benjamin , 1997). Cooper (1973) stated that the influence of temperature on root fresh and dry mass varies for different crops. As carrot is a cool season crop, cooler temperatures will increase the fresh and dry mass of the roots (Joubert , 1994; Rubatzky , 1999). Carrots are a cool-season root crop, although they can tolerate high summer temperatures. Quality and yield however, are the best under cooler conditions (Alam , 2004; Petzoldt, 2008; Alam , 2010). Carrots belong to the moderately hardy group of vegetables that are not sensitive to winter cold and frost (Joubert , 1994). The optimum temperature for growth, yield and quality range between 10 and 25°C (Joubert , 1994; Rubatzky , 1999). Yield and quality characteristics of carrots benefit from cooler growing conditions (10 to 15°C). Moderate day and relatively low night temperatures during storage root formation improve carbohydrate accumulation in carrots. At temperatures above 25°C during storage root formation, the respiration rate of the plant increases, resulting in lower yields (Rubatzky , 1999). Carrot root length and diameter positively influenced by lower temperatures (15/5°C). Where, absence green shoulder and hairiness influenced negatively by higher temperatures (28/20°C). Some of the internal quality parameters such as firmness, total soluble solids, carotene, β-pinene and caryophyllene were also significantly affected by lower temperature (15/5°C) whereas β-pinene and caryophyllene were significantly influenced by higher temperatures 28/20°C (Manosa, 2011).

The highest percentage of marketable yield (98.872%), found in 12°C (table, R1), which substantially exceeded that of 20°C (63.889%). However, the highest dead plant percentage (0.4502%) and leaf root ratio (0.60937%) accompanied to 2°C grown radish, which apparently bypassed that of 12°C. It can be inferred from these results that 20°C led to substantial lost in yield through increasing the dead plants and physiological disorders in radish. In radish, as Suzuki (1978) reported that the thickening of radish root was significantly higher at lower day/night temperatures (12/8°C) than at higher day/night temperatures (25/20°C). These results show that roots were thicker at lower temperatures than at higher temperatures although Tindall (1968); Petzoldt (2008) indicated that carrot roots tend to be thicker at warmer temperatures. Increases in temperature resulted in changes in the fluorescence parameters non-photochemical quenching (qN) and photochemical quenching (qP) in both varieties, but to a different extent. In BL and BA the increase in qP and the decrease in qN were either completed at 30°C or slightly changed following increases from 30 to 35°C. No indication of photo inhibition detected at any temperature, and the ratio of the quantum efficiencies of photosystem I1 (PSII) and O, evolution remained constant from 20 to 35°C. Measurements of 77-K fluorescence showed an increase in the photosystem I (PSI)/PSII ratio with temperature, suggesting an increase in the state transitions. In addition, measurements of fast-induction fluorescence revealed that the proportion of PSII, centers increased with increasing temperatures. The extent of both changes were maximum at 30 to 35°C, coinciding with the ratio of rates at temperatures differing by 10°C for oxygen evolution (Pastenesz and Horton, 1996).

Table R1. Yield components of radish grown in controlled cabinet under varying temperatures (*); (**)

Temperature	Pl Y kg.m^{-2}	St R Y kg.m^{-2}	Le F Y kg.m^{-2}	Mark plant %	Dead plant %	Leaf: root ratio
20 oC	B 2.3294	B 1.6345	B 0.92337	B 63.889	A 0.4502	A 0.60937
12 oC	A 4.2964	A 3.1529	A 1.03618	A 98.872	A 0.1844	B 0.31988

(*). Pl Y kg.m^{-2} = whole plant yield; St R Y kg.m^{-2} = Storage root yield; Le F Y kg.m^{-2} = leaf yield; Mark plant % = marketable yield. (**). Figures of unshared characters significantly differs at 0.05 level, Duncan.

B. Radish responses to varying irrigation levels

The highest yield of radish plants (4.0127 kg.m^{-2}) detected in 0%AWC depletion treatments, (table R2), which insignificantly differing from 33% AWC depletion (3.6706 kg.m^{-2}), and profoundly exceeded 66%AWC depletion (3.3156 kg.m^{-2}) and 100% AWC depletion (2.2528 kg.m^{-2}). The highest yield of storage roots (2.9992 kg.m^{-2}) observed in 33%AWC depletion, which insubstantially differing from 0%AWC depletion (2.8629kg.m^{-2}) and 66%AWC (2.231 kg.m^{-2}). In contrast, these two treatments highly exceeded 100%AWC (1.4816kg.m^{-2}). The highest yield of fresh leaves (1.06631kg.m^{-2}) confined to 33%AWC depletion, which insignificantly differing from 0%AWC depletion (1.05619kg.m^{-2}) and 66%AWC depletion (1.05575kg.m^{-2}). Regression analysis revealed that Yield of plant (figure, R1), yield of storage roots (figure, R2) and yield of fresh leaves (Figure, R3), linearly responded to varying irrigation levels and can be estimated by the following equations: Plant yield (kg.m^{-2}) = 4.157 – 0.001696 (AWC %); Yield of storage roots (kg.m^{-2}) = 3.129 -0.01478 (AWC %); yield of fresh leaves (kg.m^{-2}) = 1.24 -0.00289 (AWC %). In Radish, to maintain profitable yield, however, inadequate watering particularly, severe drought substantially reduced yield quantity and yield quality favoured adequate irrigation. Changes in leaf area index (LAI) from seedling stage to

harvest for different irrigation frequency treatments in showed sigmoid shapes for the LAI versus time relationship in both years. During seedling period, the LAI values for all treatments were small, and began to increase at leaf development stage. When near the succulent root formation stage, the LAI values of different treatments reached their maximum successively, and then decreased a little at the end of experiments. At harvest, LAI of the six treatments manifested that the highest irrigation frequency (F1) resulted in the least LAI (Wan and Kang, 2006). It is because a high irrigation frequency (irrigating once every day) caused a very humid region in the root zone and reduced the oxygen diffusion into the soil, which affected the activity of crop enzyme, weakened crop photosynthesis (Pezeshki 1994; Liao and Lin 1994; Huang 1994), and inhibited the development of leaf area. Gradual yield reductions accompanied with gradual reductions in water availabilities attributed to the gradual adverse effects imposed by water scarcities, where plants required urging their acquired systematic resistance to avoid drought. Genes encoding proteins with sequence similarity to proteases, and which induced by drought, have been isolated from both pea (Guerrero , 1990) and *A. thaliana* (Kiyosue , 1993; Koizumi , 1993). One of the functions of these enzymes could be to degrade proteins irreparably damaged by the effects of drought (Guerrero , 1990). During early drought in *A. thaliana,* there is an increase in levels of mRNA encoding ubiquitin extension protein (Kiyosue , 1993), a fusion protein from which active ubiquitin derived by proteolytic processing. This increase may be significant in terms of protein degradation, because ubiquitin has a role in tagging proteins for destruction. Chemical processes such as deamination, isomerization, or oxidation under drought stress may modify protein residues. It is thus likely that enzymes with functions in protein repair are upregulated in response to drought. Indeed, the response to desiccation in mosses may largely be repair based (Oliver , 1996). An example of such repair processes is the observation that L-isoaspartyl methyltransferases may convert modified L-isoaspartyl residues in damaged proteins back to L-aspartyl residues. Mudgett and Clarke (Mudgett and Klarke, 1994) have argued that such repair mechanisms could be particularly important during desiccation, when protein turnover rates are low. Although *Escherichia coli* mutants lacking the enzyme grow normally in the logarithmic phase when there is high protein turnover, they survive poorly in the stationary phase when turnover is much lower (Li and Klarke, 1992).
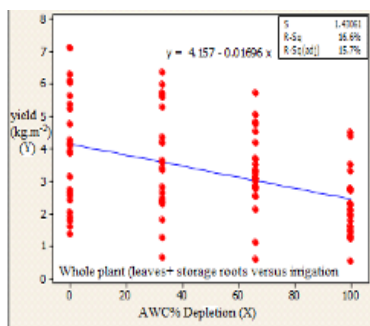

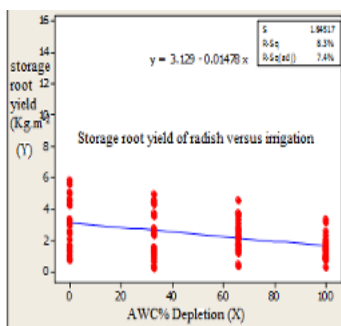Figure (R1). Whole plant yield (Kg.m^{-2}) of radish as influences by irrigation levels

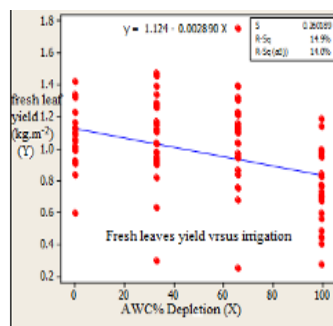Figure (R2). Storage root yield (Kg.m^{-2}) as responded to levels of irrigation

Figure (R3). Fresh leaves yield (Kg.m^{-2}) of radish as affected by irrigation

The highest marketable yield (84.549%) coincided to 66%AWC depletion (table, R2), which insubstantially differed from 0, 100% AWC depletion. However, the lowest marketable yields observed in 33% AWC depletion (76.215%). Regression analysis revealed that responses of marketable yield to varying irrigation levels overwhelmed by quadratic type and can be estimated by the following equations (figure, R4): Marketable yield (%) = 79.06 + 0.0466 (AWC %). Insignificant differences detected in the highest percentage of dead plants and leaves: roots ratio among irrigation levels. Regression analysis manifested that dead plant percentage can be estimated by cubic type equation (figure R5): Dead plants percentage (%) = 0.1844 + 0.03317 (AWC %) – 0.00087 (AWC %)^2 + 0.000006 (AWC%)^3. Leaves: roots ratio linearly responded to varying irrigation levels and can be estimated by the following equation (figure, R6): leaves: storage roots ratio = 0.4226 + 0.003051 (AWC %) – 0.000028 (AWC %)^2. Water stress highly influences the plant cell metabolism, which usually accompanied with alteration of metabolism. A role for protein phosphorylation in the drought stress response is also suggested on the basis of functional studies of the ABA-responsive RAB17 protein from maize (Gody , 1994). This protein is highly phosphorylated in vivo, probably via catalysis by casein kinase 2. The RAB17 protein has been found to be distributed between the cytoplasm and the nucleus of maize embryos, in different states of phosphorylation (Asghar , 1994; Gody , 1994). Biochemical studies showed that RAB17 binds peptides with nuclear localization signals and that the binding is dependent on phosphorylation. It has been suggested that RAB17 mediates the transport of specific nuclear-targeted proteins during stress (Gody , 1994).
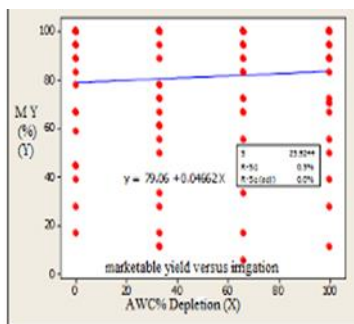
Figure (R4). Marketable yield percentage (%) as affected by levels of irrigations
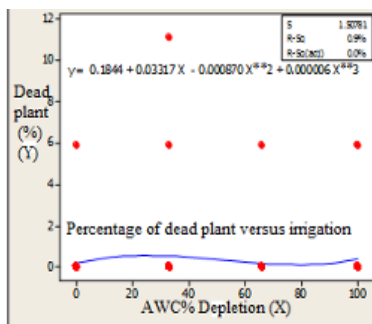

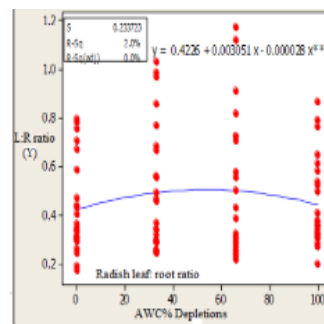Figure (R5). Dead radish plant percentage as affected by irrigation levels

Figure (R6). Responses of radish Leaf:Root ratio to irrigation levels

Table R2. Yield components of radish grown in controlled cabinet under varying irrigation levels (*); (**)

Irrigation	PI Y kg.m^{-2}	St R Y kg.m^{-2}	Le F Y kg.m^{-2}	Mark plant %	Dead plant %	Leaf: root ratio
0% awc	A 4.0127	A 2.8629	A 1.05619	B A 81.179	A 0.1844	A 0.41987
33% awc	B A 3.6706	A 2.9992	A 1.06631	B 76.215	A 0.5316	A 0.50056
66% awc	B 3.3156	B A 2.2310	A 1.05575	A 84.549	A 0.1844	A 0.49204
100% awc	C 2.2528	B 1.4816	B 0.74086	A 83.578	A 0.3688	A 0.44602

(*). PI Y kg.m^{-2} = whole plant yield; St R Y kg.m^{-2} = Storage root yield; Le F Y kg.m^{-2} = leaf yield; Mark plant % = marketable yield. (**). Figures of unshared characters significantly differs at 0.05 level, Duncan.

C. Cultivar responses to varying temperatures and irrigation levels

The obtained results revealed that Altox F1 was the most potent cultivar. It gave the highest yield of plants (3.7435 Kg.m^{-2}), which insignificantly differing from Corox F1 (3.5985Kg.m^{-2}), and significantly exceeded Topsi (2.7418Kg.m^{-2}). Other cultivars take the gap between these two cultivars (table, R3). Corox F1 showed the highest leaves yield (1.06156Kg.m^{-2}), which insubstantially differed from Altox F1 (1.00698 Kg.m^{-2}). Insignificant differences detected in yield of storage roots among cultivars. Therefore, cultivars ordered according to their significance as following: Altox F1> Corox F1> Famox F1> Topsi. Abdel ، (2013) reported radish cultivar differences reported, they attributed the cultivar responses to their genome diversity and techniques that used to conserve their genes during seed production on the mother plants. Comparative gene mapping has allowed simultaneous insights into corresponding genes of several crops and their incorporation into domestic selected material for the purpose of increasing their tolerance to drought. At a practical level, the former method includes recombination of genes of different parents, one of which at least is required to have mechanisms and properties of tolerance to drought. The latter method includes an identification of genes playing part in the expression of tolerance to drought, their isolation and transfer into different genotypes by genetic transformation (Miletic ، 2010). Yield increases of some cultivars over others suggested that these cultivars possesses higher capability to synthesize, translocate and accumulate assimilate in their organs. It was found that Short-term exposure of elevated CO_2 for plants generally leads to increased rates of leaf-level photosynthesis due to enhanced activity of ribulose-1.5-bisphosphate carboxylase/oxygenase (Rubisco) (Moore ، 1999). The response to elevated CO_2 results in an increase in leaf area, biomass accumulation, or individual plant size (Sims ، 1999; Jackson ، 1995). The rate of CO_2 assimilation by photosynthesis at twice-ambient CO_2 concentration may increase by 50% or more in the short term (Moore ، 1999). Elevated CO_2 increases total carbohydrate content and changes in hexoses/sucrose ratio. A significant increase in chlorophyll content was only in 1500 ppm treatment. Differences in photosynthetic productivity rate were within error margins. There was no effect on carbohydrate and chlorophyll contents in radish leaves seven days after returning plants to ambient CO_2, though higher photosynthetic productivity rate was in radish, previously grown under 700 ppm CO_2. In summary, leaf carbohydrate contents affect the intensity of photosynthetic pigment synthesis (Urbonaviciute ، 2006).

The highest percentage of marketable yield (88.991%) observed in Corox F1, which insubstantially differing from Famox F1, Altox F1 and significantly varied from Topsi (65.451%). Insignificant differences detected among cultivars in terms of dead plants percentages and leaves: storage roots ratio. These results suggested that the most potent cultivars are those produce highest yield acceptable by consumers. In C3 plants, the photosynthesis efficiency varies greatly. For example, of the two C3 plants turnip and sugar beet, the latter has more than 20% sucrose and is the major source of sucrose. The turnip does not synthesize sucrose efficiently. The present work examines how the

photosynthetic characteristics in relation to leaf area, chlorophyll a and b contents and their ratio, stomatal conductance, stomatal resistance, photosynthesis rate and Hill activity differ in the non-sugar producing turnip (*Brassica rapa* L. var. Snowball - family Cruciferae) and the sugar-producing sugar beet (*Beta vulgaris* L. var. Dark Red D). The total chlorophyll was higher in turnip at both stages than sugar beet. The stomatal resistance was maximum in turnip at 140 days and minimum in sugar beet at 125 days. The data show that chlorophyll contents not related to the photosynthesis rate. The latter was most profound in sugar beet at both stages as considerable amounts of photosynthates transformed into sucrose and therefore sugar beet contains over 20% sugar by weight (Siddiqui , 2006).

Table R3. Yield components of four radish cultivars grown in controlled cabinet (*); (**)

Cultivars	Pl Y kg.m^{-2}	St R Y kg.m^{-2}	Le F Y kg.m^{-2}	Mark plant %	Dead plant %	Leaf: root ratio
Topsi	C 2.7418	A 1.8232	B 0.88574	B 65.451	A 0.3472	A 0.46553
Famox F1	B C 3.1679	A 2.7085	B A 0.96482	A 84.099	A 0.5531	A 0.46911
Corox F1	B A 3.5985	A 2.3611	A 1.06156	A 88.991	A 0.1844	A 0.48945
Altox F1	A 3.7435	A 2.6820	B A 1.00698	A 86.979	A 0.1844	A 0.43440

(*). Pl Y kg.m^{-2} = whole plant yield; St R Y kg.m^{-2} = Storage root yield; Le F Y kg.m^{-2} = leaf yield; Mark plant % = marketable yield. (**). Figures of unshared characters significantly differs at 0.05 level, Duncan.

D. Radish responses to varying temperatures and irrigation levels

In general, 12°C overwhelmed irrigation levels and 20°C in term of storage roots yield. In contrast, yield of leaves responses favoured irrigation and 20°C. The highest yield of plants (5.0052 Kg.m^{-2}) confined to radish grown at 12°C irrigated with 0%AWC (table, R4), which insignificantly differed from radish grown at12°C irrigated by 33%AWC. In contrast, the lowest yield of plant confined to radish grown at 20°C irrigated by 100%AWC (1.8325 Kg.m^{-2}). The highest yield of storage roots (4.2997 Kg.m^{-2}) detected in 12°C grown radish irrigated by 0%AWC depletion, which in substantially differed from radish grown at 12°C irrigated by 33 and 66%AWC depletion treatments. However, the lowest yield of storage roots (1.1785 Kg.m^{-2}) observed in radish grown at 20°C irrigated by 100%AWC depletion. Leaves yield dominated by irrigation rather than temperature, where the highest (1.1824 Kg.m^{-2}) observed in radish grown at 12°C irrigated by 33%AWC depletion, which insignificantly differed with 12°C irrigated with 0%AWC depletion and others (table, R4). The lowest yield of leaves (0.63533 Kg.m^{-2}) observed in radish irrigated by 100%AWC depletion grown at 20°C. It seems reasonable to assume that temperature affects strength by its effect on water status. If this is valid, turgor should increase at lower temperature resulting in a higher strength in tubers of both species. However, in carrots turgor at a given water potential declined with temperature. In radish tubers, temperature affected neither pressure potential nor cutting force. Hence, there is no unequivocal effect of temperature on the mechanical component of water potential, similarly affecting strength in all plant species or all plant organs (Herppich , 2005). Growing conditions such as temperature, soil moisture, rainfall, light intensity, and day length have a significant effect on the yield and quality of carrot roots (Bloksma , 2003). The influence of varying temperatures on yield and quality parameters of carrots has been a topic for research during the last three decades (Rosenfeld and Samuelsson, 2000). Simon (1982) stated that the growth temperature of carrots affects the level of volatiles, as well as the sugar, carotenoids and texture of the roots. The best quality carrots were obtained when weather conditions favour regular uninterrupted growth (Anonymous, 2008a).

The highest percentage of marketable yield observed in adequately irrigated radish grown at 12°C. However the lowest found in radish irrigated with 33%AWC grown at 20°C (53.125%). These results confirmed that marketable yield responded better to 12°C combined with adequate watering (table, R4). In contrast, leaves: storage root ratio showed better responses to 20°C combined with adequate irrigation. The lowest ratio confined to 12°C irrigated with 100%AWC. These results suggested that 12°C and adequate irrigation favoured storage roots swellings. In contrast, adequate irrigation combined with 20°C suitable for leaf growth on account of storage roots. Radish (*Raphanus sativus*) is a vegetable, which is rich in vitamins and minerals and has medicinal values. Radish is mainly used for salad and decorative purposes and it is in high demand in the hotel industry. Radish is a cool season vegetable root crop, which grows well under tropical conditions. However, under tropical conditions, all time sufficient moisture availability is a challenging condition. Therefore, under tropical conditions there is need to optimize sufficient moisture availability for radish growth. The objective of this experiment was to investigate optimum water requirements of radish when using different mulching materials in a semi-arid environment. Water stress and chilling temperatures are two environmental constraints that limit grapevine (*Vitis vinifera* L.) photosynthesis and distribution. The former has been shown to inhibit grapevine photosynthesis, plant growth, and fruit size and yield (Delgado , 1995; Flexas , 1999; Escalona , 1999). There is evidence that, even at high light intensities, the effects of water stress on grapevine

photosynthesis mainly related to stomatal closure, although effects on Calvin-Benson cycle enzymes and PSII efficiency have been also reported (Correia , 1995; Chaumont , 1997). Low temperatures also severely limit grapevine distribution, and this crop is only sustainable between annual mean temperature isotherms of 10°C and 20°C (Jackson and Schuster, 1994). Although cool climate wine areas such as those in the Canberra region (S.E. Australia) have an annual mean temperature of 14°C, they experience average minimum temperatures above 10°C only 4 months a year, with an annual average below 6°C. Thus, it is possible that low temperatures at night will constrain grapevine physiology at the beginning and end of the growing season. Some similarities have been reported between the effects of water stress on photosynthesis and plant function and those caused to sensitive plants by chilling in the dark. Root function and water transport are decreased by low soil water temperatures because hydraulic resistance, stomatal conductance, and leaf transpiration are decreased (Hallgren and Oquist, 1990). Leaf water potential in grapevines decreased because of chilling (Balo , 1991), but little known about the effects of chilling on photosynthetic metabolism in these leaves.

Table R4. Yield components of radish grown in controlled cabinet under varying temperatures and irrigation levels (*); (**)
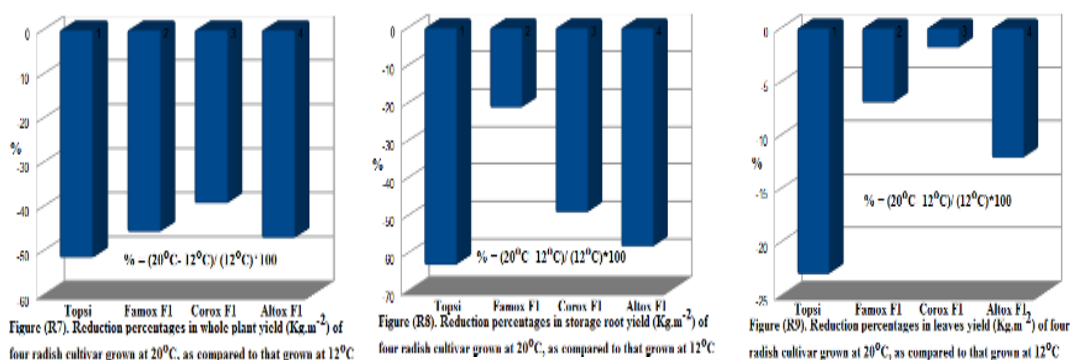
Temp:Irrig	Pl Y kg.m^{-2}	St R Y kg.m^{-2}	Le F Y kg.m^{-2}	Mark plant %	Dead plant %	Leaf: root ratio
20/0%	DC2.5253	D1.4262	BA0.98863	B 63.051	A 0.3688	BA0.5483
20/33%	DC2.3893	BDC2.4898	BA0.97438	C 53.125	A 0.6944	A0.67946
20/66%	DC2.5707	D1.4434	A1.09514	B 69.792	A 0.0000	A0.70068
20/100%	D1.8325	D1.1785	C0.63533	B 69.587	A 0.7375	BC0.50904
12/0%	A5.5002	A4.2997	A1.12375	A 99.306	A 0.0000	D0.29145
12/33%	A4.9519	BA3.5086	A1.15824	A 99.306	A 0.3688	D0.32166
12/66%	B4.0604	BAC3.0185	BA1.01636	A 99.306	A 0.3688	D0.28341
12/100%	C2.6731	DC1.7848	B0.84638	A 97.569	A 0.0000	DE0.3106

(*). Pl Y kg.m^{-2} = whole plant yield; St R Y kg.m^{-2} = Storage root yield; Le F Y kg.m^{-2} = leaf yield; Mark plant % = marketable yield. (**). Figures of unshared characters significantly differs at 0.05 level, Duncan.

E. Cultivar responses to varying temperatures

The highest yield of plant (4.9018 Kg.m^{-2}) observed in Altox grown at 12°C (table, R5), which insignificantly differing from Corox F1 grown at 12°C (4.4804 Kg.m^{-2}), and substantially exceeded the lowest Topsi grown at 20°C (1.7871 Kg.m^{-2}). Δ percentage of the differences between 20 and 12°C (figure, R7) manifested that yield of plants favoured 12°C in all investigated cultivars, especially Topsi. The highest yield of storage roots (3.7852 Kg.m^{-2}) coincided to Altox F1 grown at 12°C, which insignificantly varied from other cultivars grown at 12°C (0.9835 Kg.m^{-2}). Δ percentage of the differences between 20 and 12°C (figure, R8) manifested that yield of storage roots favoured 12°C in all investigated cultivars, especially Topsi and Altox F1. The highest leaves yield observed in responses of all cultivars to temperatures, particularly 12°C. The lowest only observed in Topsi grown at 20°C (0.76721 Kg.m^{-2}). Radish grown at 20°C generated more leaves than radish grown at 12°C. However, at harvesting dead and yellow leaves discarded. In contrast, only dicotyledonous leaves removed in radish grown at 12°C. Therefore, the higher yield of leaves that obtained from 12°C-grown radish than 20°C-grown radish is paradox. Δ percentage of the differences between 20 and 12°C (figure, R9) manifested that yield of fresh leaves favoured 12°C in all investigated cultivars, especially Topsi. These results suggested that radish cultivars preferred 12°C for epicotyl swelling rather than 20°C. Since leaf development has a strong relationship with growth, knowing changes in biometrical parameters (Montero , 2000), and chlorophyll meter could be useful for estimating radish growth and prediction of production (Le Bail , 2005). Plant growth can be defined as the increase of dry materials in plant or increase of plant parts numerically. One of the most useful indices of plant grow this the relative growth rate (RGR). It assumes that new growth related to existing biomass and is therefore exponential (Odabas , 2005). Firstly, they can change the fraction of biomass invested in leaves, stems and roots (Evans and Poorter, 2001). Temperature influences the enzymes activities through cellular membrane fluidity, which entirely depend up on the ratio between saturated and no-saturated fatty acids composed the membrane, higher membrane fluidity acquired cool resistance (Goodwin and Mercer, 1985). The decrease in photosynthesis at elevated temperature due to negative feedback effects from starch and sucrose synthesis that decrease the enzymatic activity of ribulose-1,5-bisphosphate carboxylase oxygenase (Rubisco) (Farquhar , 1980; Harley and Sharkey, 1991). Altering the physicochemical properties and functional organization of the thylakoid membrane (Berry and Bjorkman, 1980; Kim and Portis, 2005; Wise , 2004). In addition, a few studies have reported that plants grown in the presence of elevated CO_2 have higher tolerance to elevated temperatures than those that grown in normal conditions (Huxman , 1998; Taub , 2000). However, the effect of the interaction between elevated CO_2 and growth temperature on photosynthesis is controversial (Morison and Lawlor, 1999) because the effects of heat stress vary widely in both intensity and duration. Some studies suggested that a

combination of elevated CO_2 and temperature has positive effects on photosynthesis of certain plant species, including the Mojave Desert evergreen shrub, Larrea tridentata (Hamerlynck , 2000) and Cucumis sativus (Taub , 2000). For example, when leaves of cucumber grown in normal or elevated CO_2 concentration were exposed to temperatures between 28 - 48□, those grown in elevated CO_2 maintained photosystem II (PSII) efficiency (Fv/Fm) at significantly higher temperatures than those grown in a normal CO_2 concentration (Taub , 2000). Whereas, the others suggest that it has negative effects on photosynthesis of certain plant species, including Larrea tridentate (Huxman , 1998), tree seedlings (Bassow , 1994) and eucalyptus species (Roden and Ball, 1996). Most of the published studies on the effect of CO_2 and temperature have focused on grasses (Lilly , 2001; Morgan , 2001), rice (Ziska , 1997), tropical crops (Demmers-Derks , 1998; Hogan , 1991; Zhue , 1999), cotton (Reddy , 1999), or cereal crops (Alexandrov and Hoogenboom, 2000). However a few studies have examined the interactions of increased CO_2 and temperature for vegetable growth and physiological responses, such as cucumber (Taub , 2000), soybean (Ziska, 1998.

Figure (R7). Reduction percentages in whole plant yield (Kg.m^{-2}) of four radish cultivar grown at 20°C, as compared to that grown at 12°C

Figure (R8). Reduction percentages in storage root yield (Kg.m^{-2}) of four radish cultivar grown at 20°C, as compared to that grown at 12°C

Figure (R9). Reduction percentages in leaves yield (Kg.m^{-2}) of four radish cultivar grown at 20°C, as compared to that grown at 12°C

All cultivars showed excellent responses in term of marketable yield when grown at 12°C. However, cultivar responses were bad, at 20°C, particularly Topsi, which showed the lowest percentage of marketable yield (32.292%). Δ percentage of the differences between individual cultivars grown at 20°C and their corresponding at 12°C (figure, R10) manifested that marketable yield of plants favoured 12°C in all investigated cultivars, especially Topsi. Δ percentage of the differences between individual cultivars grown at 20°C and their corresponding at 12°C (figure, R11) manifested that dead plant percentage of Altox F1 occurred at 12°C, However Famox F1 found in 20°C. Insignificant differences observed among cultivars at 20°C, where the highest storage root: leaves ratio recorded. Differences among cultivars observed at 20°C, where Altox F1 gave the lowest ratio (0.27668). Δ percentage of the differences between individual cultivars grown at 20°C and their corresponding at 12°C (figure, R12) manifested that fresh leaves: storage roots ratio of plants favoured 20°C in all investigated cultivars, especially Famox F1, Corox F1 and Altox F1. Chinese cabbage and radish, the important cool season crops are good models to study the effects of climate changes on agricultural production. They are more adversely affected by elevated temperatures than other warm season crops, and greatly influenced by elevated CO_2 in terms of change in stomatal resistance (Mishra , 1999), and in root to shoot ratio (Idso , 1988; Morison and Gifford, 1984). This study examined the effects of elevated CO_2 and temperature on the growth, photosynthesis rate, gas exchange, and rate of nutrient uptake in the radishes and cabbages. The highest root fresh mass for both cultivars was also obtained at 10°C, with "Star 3002" with the highest mass (39.12 g) followed by "Nectar" (34.26 g). Both cultivars exhibited the highest root dry mass at the lower temperature treatment (10°C) with "Star 3002" having a higher root dry mass (4.15 g) than "Nectar" 3.87 g (Manosa, 2011). External quality parameters such as root length and diameter differed significantly between the temperature treatments and only the length of carrot roots did not differ significantly between the cultivars. Both "Nectar" and "Star 3002" exhibited the longest roots at 10°C and the shortest roots at 18°C. Root diameter for both cultivars was significantly greater at 10°C than at 18°C. The only defects observed were green shoulder and misshapen roots. Although not significant, the percentage green shoulders and misshapen roots were higher at 18°C than at 10°C. Carrots were significantly firmer at the low temperature (10°C) than at 18°C. The total soluble solid content of carrots however, grown at 18°C was significantly higher than radish grown at 10°C (Manosa, 2011). Carrots in the seedling phase will endure frosts and temperatures as low as -7°C. The top growth is slow at temperatures below 4°C, and consecutive severe frosts will cause the leaves to die (Joubert , 1994; Anonymous, 2008b). Furthermore, once the soil freeze, crown damage occurs as small hairlines and horizontal splits on the surface of the storage root. Carrot storage roots are more vulnerable to frost damage when the plants are mature. Still, storage roots will withstand

severe frost if they are not showing above the soil, and also provided the soil does not freeze. Frost-damaged roots tend to be of a poor quality (Anonymous, 1997).

Figure (R10). Reduction percentages in marketable yield (%) of four radish cultivar grown at 20^0C, as compared to that grown at 12^0C

Figure (R11). Reduction percentages in dead plant (%) of four radish cultivar grown at 20^0C, as compared to that grown at 12^0C.

Figure (R12). Reduction percentages in storage root:shoot ratio of four radish cultivar grown at 20^0C, as compared to that grown at 12^0C
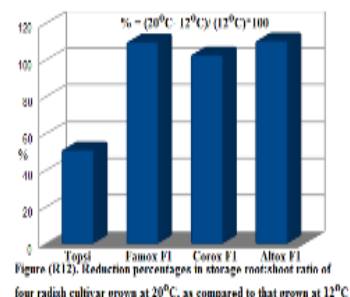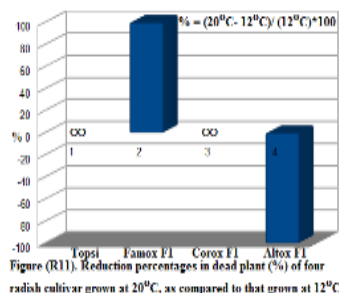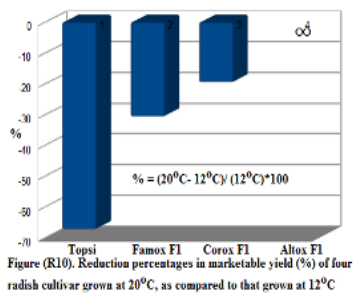
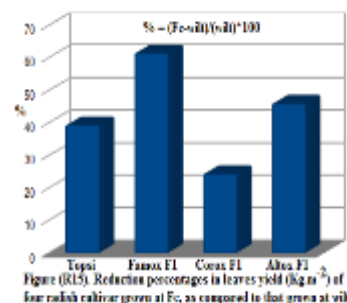Table R5. Yield components of four radish cultivars grown in controlled cabinet under varying temperatures (*); (**)

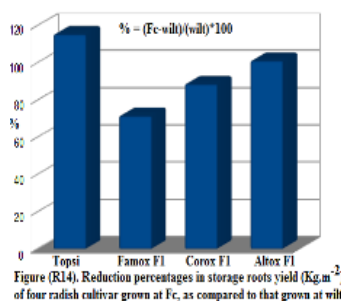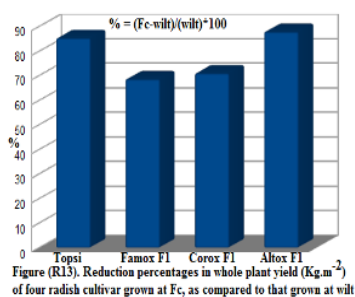| Temp. Cvs	PI Y kg.m^{-2}	St R Y kg.m^{-2}	Le F Y kg.m^{-2}	Mark plant %	Dead plant %	Leaf: root ratio
20 T	E1.7871	C0.9835	B0.76721	D32.292	A0.6944	A0.5576
20 F	ED2.229	BAC2.3852	BA0.93159	C68.893	A0.7375	A0.63376
20 C	D2.7166	BC1.5903	A1.05052	B79.371	A0.3688	A0.65399
20 A	D2.5851	BC1.5788	BA0.94417	BC75	A0	A0.59213
12 T	C3.6964	BA2.6628	A1.00428	A98.611	A0	B0.37347
12 F	BC4.1068	BA3.0318	A0.99806	A99.306	A0.3688	B0.30446
12 C	BA4.4804	A3.1319	A1.07261	A98.611	A0	B0.32491
12 A	A4.9018	A3.7852	A1.06979	A98.958	A0.3688	B0.27668

(*). PI Y kg.m^{-2} = whole plant yield; St R Y kg.m^{-2} = Storage root yield; Le F Y kg.m^{-2} = leaf yield; Mark plant % = marketable yield. (**). Figures of unshared characters significantly differs at 0.05 level, Duncan.

F. Cultivar responses to irrigation levels

The highest yield of plants (4.4602 Kg.m^{-2}) observed in adequately irrigated Altox F1 (table, R6), which significantly differing from the lowest yield of plants (1.8296 Kg.m^{-2}), detected in Topsi irrigated by 100%AWC depletions. Δ percentage of the differences between individual cultivars grown at 0%AWC and their corresponding at 100%AWC (figure, R13) showed that all cultivars performed better yield of plants under adequate irrigation, particularly, Altox F1 and Topsi. The highest yield of storage root (4.7418 Kg.m^{-2}) found in adequately irrigated Altox F1, which significantly bypassed the lowest yield of storage roots observed in wilted Topsi cultivar (1.1079 Kg.m^{-2}). Δ percentage of the differences between individual cultivars grown at 0% AWC and their corresponding at 100%AWC (figure, R14) exhibited that all cultivars performed better yield of storage roots under adequate irrigation, especially Topsi. The highest yield of fresh leaves (1.1725 Kg.m^{-2}) observed in Famox F1 irrigated with 66%AWC deletions, which insignificantly varied from Corox F1 irrigated with 33%AWC depletion and significantly exceeded the lowest yield of fresh leaves (0.646 Kg.m^{-2}) detected in wilted Famox F1. Δ percentage of the differences between individual cultivars grown at 0%AWC and their corresponding at 100%AWC (figure, R15) showed that all cultivars preferred adequate irrigation, particularly Famox F1. These results suggested that Altox F1 revealed higher yield under adequate irrigation and severe drought, Topsi highly reduced it yield under adequate irrigation and severe drought. Famox F1 manifested the lowest difference between adequate irrigation and severe drought, in other words Famox F1 possesses higher drought resistance to drought, however, it gave lower yield than Altox F1 under drought conditions. Therefore, Famox F1 can be used for gene materials in drought resistance program. Changes in leaf area index (LAI) from seedling stage to harvest for different irrigation frequency treatments in showed sigmoid shapes for the LAI versus time relationship in both years. During seedling period, the LAI values for all treatments were small, and began to increase at leaf development stage. When near the succulent root formation stage, the LAI values of different treatments reached their maximum successively, and then decreased a little at the end of experiments. At harvest, LAI of the six treatments manifested that the highest irrigation frequency (F1) resulted in the least LAI (Wan and Kang, 2006). It is because a high irrigation frequency (irrigating once every day) caused a very humid region in the root zone and reduced the oxygen diffusion into the soil, which affected the activity of crop enzyme, weakened crop photosynthesis (Pezeshki 1994; Liao and Lin 1994; Huang , 1994), and inhibited the development of leaf area. In both carrot taproots and radish tubers, tissue strength, as indicated by average tissue cutting force, increased with rising water potential and decreasing water deficit. Similar relations between water potential and cutting force or cutting energy, or tensile strength, respectively, have been reported for other produce (De Baerdemaker , 1978; Hiller

and Jeronimidis, 1996; De Belie , 2000). However, others reported that highly turgid products are more brittle, exhibit a lower tissue strength as well as a reduced resistance to bruising, or splitting and breaking damage than flaccid ones (Lin and Pitt, 1986; McGarry, 1993; Kokkoras, 1995; Hiller and Jeronimidis, 1996; Bajema , 1998). This seeming disagreement may simply be due to the complexity of tissue strength. Hiller and Jeronimidis (1996) showed that increasing the relative turgor enhanced cutting energy but lowered the work of fracture in potato tissue. Furthermore, De Baerdemaeker (1978) found that tensile strength of potato and apple tissue increases with increasing water potential while compressive strength declined. In apple and pears, the failure mode itself depends on the stage of maturity (De Belie , 2000). In addition, the correct determination of fracture work or energy can sometimes evolve serious problems (Vincent, 1990).

Figure (R13). Reduction percentages in whole plant yield (Kg.m^{-2}) of four radish cultivar grown at Fc, as compared to that grown at wilt

Figure (R14). Reduction percentages in storage roots yield (Kg.m^{-2}) of four radish cultivar grown at Fc, as compared to that grown at wilt

Figure (R15). Reduction percentages in leaves yield (kg.m^{-2}) of four radish cultivar grown at Fc, as compared to that grown at wilt

The highest percentage of marketable yield (95.139%) observed in Corox F1 irrigated by 66% AWC depletion, which significantly exceeded the lowest (56.9441%) found in Topsi irrigated with 33% AWC depletions. Δ percentage of the differences between individual cultivars grown at 0% AWC and their corresponding at 100% AWC (figure, R16) showed that all cultivars accept Altox performed better under drought than adequate irrigation. Δ percentage of the differences between individual cultivars grown at 0% AWC and their corresponding at 100% AWC (figure, R17) showed that dead percentage of Famox F1 dead plants were higher at 100%AWC depletion. Δ percentage of the differences between individual cultivars grown at 0%AWC and their corresponding at 100%AWC (figure, R18) manifested that ratio leaves to storage roots mainly occurred with 100% AWC depletion in all cultivars accept Altox F1. In northern China, radish is widely cultivated and generally planted in raised beds in spring and autumn. Radish yields and quality dramatically fluctuate due to frequent droughts and poor irrigation management. Drip irrigation lends itself readily to establish a nearly constant water regime in the root zone and the fluctuation of the SWP can be held to a minimum without difficulties (Horton , 1982), which ensure plants growing under proper soil water for the optimum yield and size. A major problem under severe dehydration is that the loss of water leads to crystallization of cellular components, which in consequence damages cellular structures. This may be counteracted by LEA proteins, and some of the LEA proteins could essentially be considered compatible solutes, which supports the likely role of sugars in maintaining the structure of the cytoplasm in the absence of water (Ingram and Bartles, 1996). The products of two drought-induced genes isolated by differential screening have sequence similarity to heat-shock proteins (Kiyosue , 1994). These encoded proteins are probably chaperonins, involved in protein repair by helping other proteins to recover their native conformation after denaturation or misfolding during water stress. The low molecular weight heat-shock proteins (Coca , 1994) may also be chaperonins. This function has been demonstrated for a mammalian low-molecular-weight heat-shock protein (Jakob , 1993). An alternative function may be in the sequestration of specific mRNAs in cells subjected to drought (Nover , 1989).
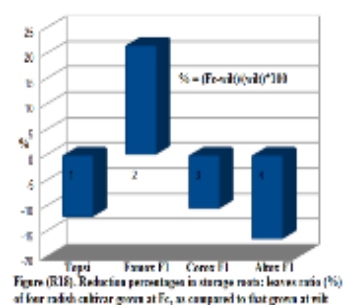

Figure (R16). Reduction percentages in marketable (%) of four radish cultivar grown at Fc, as compared to that grown at wilt

Figure (R17). Reduction percentages in dead plants (%) of four radish cultivar grown at Fc, as compared to that grown at wilt

Figure (R18). Reduction percentages in storage roots: leaves ratio (%) of four radish cultivar grown at Fc, as compared to that grown at wilt
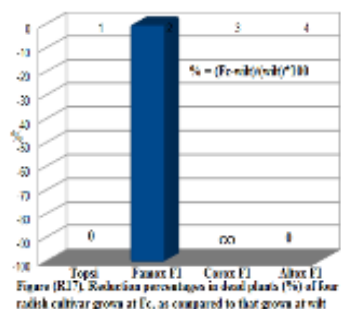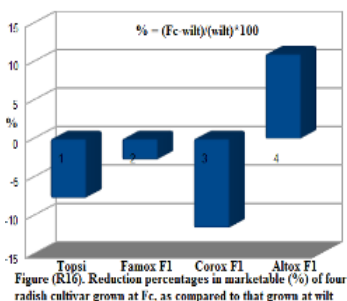
Table R6. Yield components of four radish cultivars grown in controlled cabinet under varying irrigation levels (*); (**)

Irrig: Cvs	Pl Y kg.m^{-2}	St R Y kg.m^{-2}	Le F Y kg.m^{-2}	Mark plant %	Dead plant %	Leaf: root ratio
0%T	EBDC3.388	BC2.3879	EBDAC0.9934	E D 66.667	A 0.0000	A0.4268
0%F	EBDAC3.4881	BC2.3451	BDAC1.053	B A C 85.417	A 0.0000	A0.4466
0%C	BA4.5347	BAC3.3171	BAC1.0723	B A C 81.658	A 0.7375	A0.4226
0%A	A4.6402	BA3.4017	BAC1.1061	B A 90.972	A 0.0000	A0.3835
33% T	EDFC3.1641	BC2.0477	BDAC1.035	E 56.944	A 1.3888	A0.5048
33% F	EBDAC3.5115	A4.7418	EBDAC0.9721	B D C 77.778	A 0.0000	A0.5187
33% C	BAC3.8939	BC2.2112	A1.1725	B A C 86.806	A 0.0000	A0.5068
33 % A	BAC4.1128	BAC2.9961	BAC1.0856	B A C 83.333	A 0.7375	A0.472
66% T	EGDF2.5854	BC1.7491	EDFC0.8094	E D 65.972	A 0.0000	A0.4414
66% F	EBDAC3.6031	BC2.3774	A1.1882	B A C 85.417	A 0.7375	A0.5406
66% C	EDC3.3196	BC2.1562	BA1.1445	A 95.139	A 0.0000	A0.5628
66% A	BDAC3.7541	BC2.6412	BAC1.0809	B A 91.667	A 0.0000	A0.4234
100%T	G1.8296	C1.1079	EF0.7052	D C 72.222	A 0.0000	A0.4891
100%F	GF2.0691	BC1.3697	F0.646	B A 87.786	A 1.4750	A0.3705
100%C	EGDF2.6458	BC1.7599	EBDFC0.857	B A 92.361	A 0.0000	A0.4657
100%A	EGF2.4667	BC1.6889	EDF0.7553	B A C 81.944	A 0.0000	A0.4587

(*). Pl Y kg.m^{-2} = whole plant yield; St R Y kg.m^{-2} = Storage root yield; Le F Y kg.m^{-2} = leaf yield; Mark plant % = marketable yield. (**). Figures of unshared characters significantly differs at 0.05 level, Duncan.

G. Cultivar responses to varying temperatures and irrigation levels

The highest yield of plants (6.1604 kg.m^{-2}) observed in adequately irrigated Altox F1 grown in 12°C cabinet (table R7), which significantly differing from the lowest yield of plants (1.4297 kg.m^{-2}) recorded in wilting Topsi grown at 20°C. These results suggested that Topsi exposed to severe drought and high temperature showed drastic reduction in plant yield. Kamada (1995) suggest that heat induced activation of a particular pathway is in response to increased membrane fluidity in the cell wall. The cell detects this weakness in the cell wall by sensing stretch in the plasma membrane. Examples such as this from simple systems may provide the conceptual framework for devising experiments in plants. Water potential and pressure potential positively correlated with strength and stiffness in carrot and radish, but only stiffness showed a significant correlation with water status. Beyond wilting, the effect of water potential on mechanical properties was less pronounced (Herppich , 2005).

The highest yield of storage roots (5.95 Kg.m^{-2}) detected in Famox F1 irrigated by 33%AWC grown at 20°C, which substantially differed from the lowest obtained yield of storage roots (0.839 Kg.m^{-2}) found in Topsi grown at 20°C irrigated by 100%AWC. Drought adversity referred to the drought-activated signal transmission process has begun to be dissected at the molecular level, mostly based on studies of isolated drought-responsive genes. Endogenous ABA levels have been reported to increase as a result of water deficit in many physiological studies, and therefore ABA is thought to be involved in the signal transduction (Chandler and Robertson, 1994; Giraudat , 1994). Many of the drought-related gene scan be induced by exogenous ABA; however, this does not necessarily imply that all these genes are also regulated by ABA in vivo. Many of the changes in mRNA levels observed during drought reflect transcriptional activation. Treatment with ABA can also induce these changes, and this treatment has been utilized for setting up experimental systems to define *cis-* and *trans-*acting elements. *cis-* and *trans-*acting elements involved in ABA-induced gene expression have been analyzed extensively (Giraudat , 1994).

The highest yield of fresh leaves (1.2837 Kg.m^{-2}) coincided to Famox F1 irrigated with 66%AWC depletion grown at 20°C, which significantly exceeded the lowest yield of fresh leaves (0.5357 Kg.m^{-2}) accompanied to Famox F1 irrigated by 100%AWC grown at 20°C. These results revealed the dominance of irrigation levels. The best-characterized *cis-*element in the context of drought stress is the ABA-responsive element (ABRE), which contains the palindromic motif CACGTG with the G-box ACGT core element (Giuliano , 1988). ACGT elements have been observed in a multitude of plant genes regulated by diverse environmental and physiological factors. Systematic DNA-binding studies have shown that nucleotides flanking the ACGT core specify the DNA-protein interactions and subsequent gene activation (57). G-box-related ABREs have been observed in many ABA-responsive genes, although their functions have not always been proven experimentally. The best studied examples of these ABRE promoter elements are Em1a from wheat and Motif I from the rice *rab 16A* gene (Marcotte , 19889; Mundy , 1990). Multiple copies of the elements fused to a minimal 35S promoter confer an ABA response to a reporter gene (Skriver , 1991) , which supports the hypothesis that ABREs are critical for the ABA induction of relevant genes (although it is difficult to explain why single copies are not sufficient for this response). The ABA effect on transcription was orientation independent in both the wheat and rice elements, which suggests that they possibly function as enhancer elements in their native genes. Electrophoretic mobility shift assays and methylation interference foot printing have

shown that both Em1a and Motif1 interact with nuclear proteins; these DNA-binding proteins are constitutively expressed in an ABA independent manner (Mundy , 1990). Quagliotti (1967) reported that the tallest carrot plants produced at a constant temperature of 14°C and the shortest plants at 26°C. Libner (1989) found that plant height of carrots decreased dramatically as temperature rose above 18°C. Ddiurnal variation in temperature regimes were used, the tallest plants during first few weeks were produced at the 28/20°C treatment, but as the season progressed the tallest plants for both cultivars were produced at 24/10°C. In the same period and in most case carrot plants at the 15/5°C did not differ significantly from the 24/10°C treatment. Numerous researchers also reported on the positive effect of cooler temperatures on plant height for other crops such as radish (Suzuki, 1978) and sugar beet (Ulrich, 1954).

The highest percentage of marketable (100%) coincided in all cultivars irrigated by 0% AWC depletion grown at 12°C, where the lowest percentage of marketable yield (16.667%) observed in Topsi irrigated by 33%AWC grown at 20°C. These results revealed the effective influence of temperatures. In cold tolerant plants, especially some tomato cultivars (Smirnova and Goranko, 1992), for example, *Sibirslie skorospelye* (Novitskaya , 2000). Phase transitions are absent at low above zero temperature (5–6°C), which is also explained by an increased ratio of unsaturated to saturated FAs (Trunova, 2007), and by an increase in the lipid content in chloroplast membranes (Novitskaya and Trunova, 2000). This results in enhanced functional activity of the membranes in cold tolerant plants at a wide range of above zero temperature (Lyons, 1973). Plant cold tolerance related to the tolerance of photosynthesis to low temperature, the character of carbohydrate metabolism, and conditions of illumination (Klimov, 2001). Radish belongs to cold tolerant plants enduring temperature lowering down to –2°C; it is sensitive to weak magnetic field, and we have the effects of this weak magnetic field on the lipid composition of adult plants (Novitskaya, , 2008). Photosynthesis is one of the first processes to be affected when chilling sensitive plants are exposed to low temperatures. Even though molecular mechanisms of chilling damage are still not clear, lipid composition affecting cell membrane stability and function thought to be the main cause (Nishida and Murata, 1996). It is necessary to distinguish the effects of chilling in light or in darkness. Chilling in darkness causes reductions in the light-saturated rate of CO_2 assimilation and PSII-associated electron transport at room temperature in tomato (Hallgren and Oquist, 1990).

The highest leaves: storage roots ratio (0.8162) found in Corox F1 irrigated by 66%AWC depletion grown at 20°C, which substantially exceeded the lowest ratio (0.24464) detected in adequately irrigated Corox F1 grown at 12°C (table, R7). These results showed that adequate irrigation combined with 12°C tended to improve the hypocotyl swelling and produce well performed storage roots on the account of leaves and vice versa. Kingston-Smith (1997) reported decreases in the CO_2 assimilation rate after chilling maize leaves in low light, and Fryer (1998) observed the same effects, without effects on PSII activity, in field-grown maize during periods of low temperature. Chilling in the light may impair activation of the carbon reduction cycle (Sassenrath , 1990) and lead to photoinhibition (Oquist and Huner, 1991; Terashima , 1993). Long-term exposure to combined high light and low temperatures is needed to photo inhibit grapevines; short-term exposure (less than 6 h) does not affect photochemical yields (Gamon and Pearcy, 1990; Balo , 1991; Chaumont , 1997). Increases in the ratio of electron transport to CO_2 assimilation in leaves have been reported to occur under chilling conditions (Fryer , 1998) and under drought conditions (Flexas , 1999).

Table R7. Yield components of four radish cultivars grown in controlled cabinet under varying temperature and irrigation levels (*); (**)

Temp:Irrig: Cvs	Pl Y kg.m^{-2}	St R Y kg.m^{-2}	Le F Y kg.m^{-2}	Mark plant %	Dead plant %	Leaf: root ratio
20 0% T	JK1.8049	E0.862	A-G0.9469	HI33.333	B0	A-E0.5127
20 0% F	JK2.0091	E1.045	A-G0.959	C-F 73.611	B0	A-E0.5856
20 0% C	F-J3.1674	B-E1.914	A-G0.9918	E-G63.317	AB 1.475	A-E0.5992
20 0% A	F-J3.1199	B-E1.883	A-E1.0568	A-E81.944	B0	A-E0.4957
20 33% T	I-K2.2249	E1.23	A-G0.8912	I 16.667	A 2.778	A-E0.5892
20 33% F	I-K2.4702	A5.95	A-G0.948	FG55.556	B0	A-C0.7368
20 33% C	I-K2.5035	DE1.35	A-C1.1401	C-E73.611	B0	A-C0.7264
20 33% A	I-K2.3585	DE1.43	A-G0.9183	D-G66.667	B0	A-D0.6654
20 66% T	K1.689	E1.003	D-G0.6512	HI31.944	B0	A-E0.5933
20 66% F	F-K2.8993	C-E1.57	A1.2837	E-F70.833	B0	AB0.7928
20 66% C	G-K2.7169	DE1.449	AB1.2633	A-C 93.056	B0	A0.8162
20 66% A	F-K2.9775	B-E1.751	A-C1.1824	A-E 83.333	B0	A-E0.6005
20 100% T	K1.4297	E0.839	FG0.5795	GH47.222	B0	A-E0.5353
20 100% F	K1.5373	E0.976	G0.5357	B-F 75.572	A 2.95	C-E0.4199
20 100% C	H-K2.4785	C-E1.648	B-G0.8069	A-D 87.5	B0	A-E0.4741
20 100% A	JK1.8845	E1.251	E-G0.6192	D-F68.056	B0	A-E0.6069
12 0% T	A-D4.9712	A-E3.914	A-E1.0398	A 100	B0	DE0.341
12 0% F	A-D4.967	A-E3.645	A-C1.147	AB 97.222	B0	DE0.3076
12 0% C	AB5.902	A-C4.72	A-C1.1528	A 100	B0	E0.246
12 0% A	A6.1604	AB4.92	A-C1.1554	A 100	B0	E0.2712
12 33% T	C-H4.1033	A-E2.865	A-C1.1788	AB 97.222	B0	C-E0.4205
12 33% F	A-D4.5527	A-E3.534	A-F0.9962	A 100	B0	D-E0.3006
12 33% C	A-C5.2843	A-E3.073	A-C1.205	A 100	B0	E0.2871
12 33% A	AB5.8671	A-D4.563	AB1.2529	A 100	AB 1.475	E0.2785
12 66% T	D-I3.4818	B-E2.495	A-F0.9675	A 100	B0	E0.2894
12 66% F	B-F4.3068	A-E3.185	A-D1.0928	A 100	AB 1.475	E0.2885
12 66% C	C-H3.9223	A-E2.863	A-E1.0256	AB 97.222	B0	DE0.3093
12 66% A	A-D4.5308	A-E3.531	A-G0.9795	A 100	B0	E0.2464
12 100% T	I-K2.2294	DE1.377	A-G0.8309	AB 97.222	B0	B-E0.443
12 100% F	H-K2.6008	B-E1.763	C-E0.7562	A 100	B0	DE0.3212
12 100% C	G-K2.8131	B-E1.871	A-F0.9071	AB 97.222	B0	A-E0.4573
12 100% A	H-K3.0489	B-E2.127	A-F0.8913	AB 95.833	B0	DE0.3106

(*). Pl Y kg.m^{-2} = whole plant yield; St R Y kg.m^{-2} = Storage root yield; Le F Y kg.m^{-2} = leaf yield; Mark plant % = marketable yield. (**). Figures of unshared characters significantly differs at 0.05 level, Duncan.

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